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MENDELIAN HEREDITY IN MAN

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DURING the last ten years the Mendelian principles of heredity have been applied with remarkable success to various characters in many kinds of plants and animals. These Mendelian experiments have given rise to the new science of Genetics. In the absence of controlled matings, the analytical methods of Genetics are obviously difficult to apply to Man, and for his analyses, the student has to rely on observations of the results of random matings. In spite of this heavy handicap, and notwithstanding the almost equally serious drawback of having to deal with small families, considerable progress has been made, and there is no doubt that at the present time we have sufficient positive evidence to demonstrate the working of Mendelian heredity in Man, and to encourage students to pursue their investigations over a wider field. A large amount of work has been done recently in the way of collecting pedigrees from different sources, illustrating the inheritance of various characters in Man, and in certain cases where the pedigrees have been critically analysed in the light of the Mendelian principles, some valuable results have been obtained. The results obtained by Farabee (10), Nettleship (21), Davenport (3-7), Gossage (12),

Mudge (19), Drinkwater (9), Goddard (11), Salaman (23), and Jordan (16), provide good illustrations of the value of this method of work.

During the past ten years the writer has adopted the somewhat different method of making personal observations on the individual characters of the parents and children living in and about the village of Burbage, Leicestershire. (This district consists of an industrial village with outlying hamlets, altogether comprising a population of about 3,000 persons.) In all Mendelian researches, whether in plants, animals or Man, the advantages of personal observation seem far to outweigh the disadvantages of small numbers in a limited area.

In view of the various characters touched upon in this paper, it is, of course, mpossible to attempt to deal with any single character exhaustively, consequently the paper can only be regarded as an introductory sketch. Further details may be found in the literature cited and in the forthcoming Reports of the Burbage Experiment Station.

Eye-Colour.

Human eye-colour depends mainly on the colour of the iris, which is largely determined by the presence or absence of two distinct layers of pigment. In the true blue eye only one of these pigmentary layers is visibly present, the posterior purple pigment of the choroid, which, being reflected through the fibrous structure of the iris produces the blue colour. In the absence or partial absence of this pigment the eye appears to be "pink" as in albinos. In the ordinary brown eye two layers of pigment are present, for in addition to the posterior purple layer there is also an anterior brown layer, in front of the iris.

In order to distinguish eyes with two layers from eyes with one layer of visible pigment, the writer (14) in 1907 called the one Duplex and the other Simplex, and further found that these two types of eyes in their genetics follow the ordinary Mendelian rules, Duplex being dominant and Simplex recessive. Or applying the presence and absence method—presence of the brown front layer is dominant to its absence.

Simplex eyes may be any shade of blue or grey according to

the fineness or coarseness of the structure of the iris, consequently baby-blue eyes may develop into adult grey eyes. Duplex eyes may be any colour from " black " (very dark brown) to blue, according to the amount of brown pigment present on the front of the iris. If the amount of brown pigment is small such Duplex eyes may be easily mistaken for Simplex when viewed at a short distance or in a bad light. A close lateral inspection in a good light will, however, generally determine the presence or absence of visible pigment in front of the iris, without the assistance of a lens.

An attempt to differentiate the various grades of blue and grey Simplex eyes has so far proved unsuccessful owing partly to their apparent continuity and partly to their changes with age. An attempt to differentiate the various grades of Duplex eyes has been more successful, though experience shows that great caution is necessary to avoid the many pitfalls that exist even for the wary.

In 1907 the writer suggested that Duplex eyes might be classified into three definite patterns, Self, Ringed, and Spotted.

In the Self pattern, the brown pigment is distributed over the entire surface of the iris, the rays being pigmented to the periphery. To this class belong eyes generally known as " black," dark brown, brown, red-brown, yellow-brown, green-brown and green, according to the density of the melanic pigment covering the front of the iris, and possibly also in some cases, to the existence of a distinct yellow or orange pigment (lipochrome) diffused with the brown melanin.

In the Ringed pattern the brown pigment is confined to a ringed area round the pupil, leaving a solid blue or grey rim round the periphery. In some cases the ring of pigment is clearly defined and narrow, while in others it is irregular in outline and broader with fimbriated rays. To this class belong eyes generally known as grey-brown, dark grey, grey, grey-green, and blue-green.

In the Spotted pattern the inner ring is altogether absent or broken up into discrete patches, blotches or spots. These spots are usually irregular in size, number and distribution over the blue or grey ground colour. Similar spots are to be found

in certain eyes of the Self and Ringed patterns, but these are on a lighter duplex ground, while those of the true spotted pattern are on a simplex ground colour.

With regard to the genetics of these Duplex patterns, so far as adults are concerned the Self seems to behave as a dominant to the Ringed which is recessive, following the ordinary Mendelian rules. In the case of juveniles, however, great care is necessary, because since 1905 I have found several cases in which the Ringed pattern has developed into the Self pattern with age. The Spotted pattern is rather rare in my material, but, so far as the evidence goes, it appears to behave as a dominant both to the Self and Ringed patterns, suggesting that it may be due to the presence of an inhibitor. It is interesting to note the close analogy between the genetics of the Self, Ringed and Spotted patterns of eyes in Man, and the Self, Dutch and English patterns of coat colour in rabbits.

Dr. C. B. Davenport and Mrs. Davenport (3), of the Carnegie Institution of Washington (who discovered the Mendelian nature of eye-colour almost simultaneously with the writer (13)), make three grades of eye-colours, brown, grey and blue in the order of their dominance. This is certainly a more simple interpretation of the facts which, though broadly in agreement with the writer's scheme, differs from it in one important particular, inasmuch as it leaves untouched the peculiar problem of the Spotted eye.

In following up their scheme, Davenport and Davenport find that the darker grade of eye-colour is always dominant to the lighter grade, so that no children have darker eyes than the darker parent. In order to test this broad generalisation of the "Non-transgressibility of the Upper Limit," I have attempted to grade the eye-colour shades in some of the Burbage families from 0-10 according to the amount of brown pigment present on the iris.

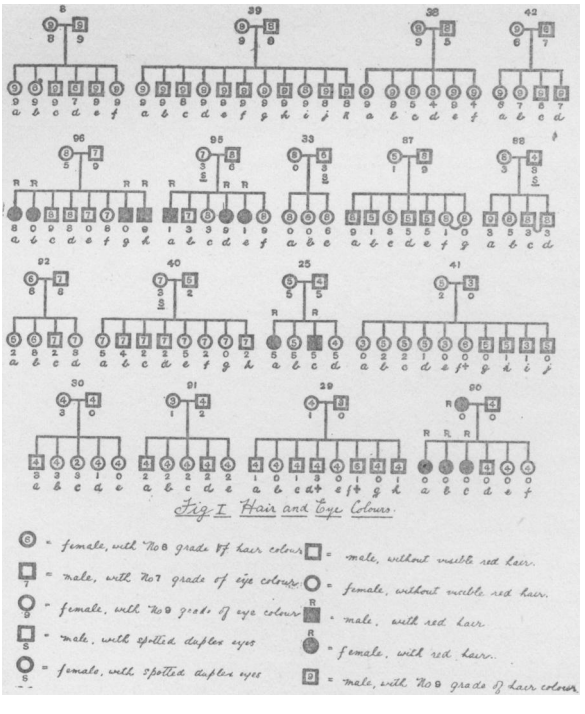
Thus 0 represents the blue or grey Simplex eye with no brown pigment: 1, 2 and 3 are blue or grey Duplex eyes of the Spotted or Ringed patterns: 4 is a dark grey, grey-green, or grey-brown, a broadly ringed pattern: 5, 6, 7, 8 and 9 are Self patterns varying in shade from light green to dark brown, and

10 represents "black" eyes (really a black-brown) like those found in some negroes, but not met with in the Burbage families.

According to this method a numerical grading of the brown pigment is obtained by the two-fold consideration of distribution and density, the shade of the blue or grey ground-colour being ignored as far as possible.

The following families have been worked out on this system, the figures *underneath* each square and circle representing the estimated grade of brown pigmentation in the eyes.

FIG. I.



The above pedigrees, on the whole, tend to confirm the Davenports' generalisation, the striking exceptions being the cases of Spotted Duplex eyes which, notwithstanding their lowness of grade, give offspring of a higher grade than either parent (see families 40, 88, 95 and 33). The single case of family 29 (*d*), where the higher parental grade 1 gives a solitary instance of grade 3 is at present inexplicable, as both the 1 and 3

grades concerned are apparently of the ordinary ringed pattern. Family 25 is interesting as a case of an apparently pure-breeding 5 grade, and the youngest daughter of this family (25*d*) is a specific case of the change with age from a Ringed to a Self Duplex: in 1905 her eyes were classed as Ringed Duplex representing grade 3, whereas in 1911 they were Self Duplex representing grade 5. The increase of pigment in this case was twofold, representing an increase of 1 grade in distribution and 1 grade in density.

Hair Colour.

Davenport & Davenport (5) have shown that two distinct pigments may be present in human hair, a granular brown melanin and a diffused red lipochrome. Somatic interaction between these two pigments gives complicated results, so that it will be convenient to deal with them separately.

Brown Pigment.

According to the Davenports, human hair with brown pigment varies in shade from black to light yellow according to the amount of brown pigment present. Unlike similar hair colours in rabbits, mice, and guinea-pigs, which experiments have shown to be discontinuous, the shades of human hair appear to be continuous. The Davenports, however, conclude that in all cases the higher and darker grade is dominant to the lower and lighter grade, which is recessive. Consequently, children in no case have darker hair than their darker parent, being another illustration of the Davenports' generalisation of the "Non-transgressibility of the Upper Limit." In order to test this generalisation with my own material, I have attempted to grade the brown hair colours of some of the Burbage families from 0-10, grade 0 representing white "albino" hair with no pigment, and grade 10 representing jet black hair with no trace of brown. Neither of these grades has yet been found in my material. Grades 1 and 2 represent silvery cream and pale yellow hair, so far only met with in juveniles. Grades 3 and 4 represent yellow and yellow-brown hair: grades 5 and 6 represent medium brown and deep brown hair: while grades

7, 8, and 9 represent dark-brown, black-brown and ordinary "black" hair respectively.

A serious difficulty however arises, a difficulty which at one time I feared would be insurmountable, and that is the frequent and considerable changes of colour that human hair undergoes in the progress of development and decay during the life of the individual. These changes of colour from birth to death appear to be very variable in different individuals. In many individuals the true adult hair-colour of the head can only be observed during a brief period of time, and often before the children reach the adult stage the parents are already grey.

In view of these facts any first-hand investigation of the inheritance of human hair-colour by comparison of parents with children would appear to be extremely difficult, if not altogether impracticable. Fortunately, however, the writer has found that the colour of the eye-lashes at practically any age seems to be a fairly reliable index to the adult head-hair. Generally speaking, one finds that in very young children the pigment of the eye-lashes develops much more quickly than that of the eye-brows and head hair, and with few exceptions the colour of the eye-lashes in juveniles may be taken as a fairly approximate index of what the adult hair will be. Similarly in old people with grey hair, the colour of the eye-lashes will generally give one a fair idea of what the adult hair was like.

It is true that a few cases have been observed in normal adults where the eye-lashes are darker or lighter than the hair of the head and eye-brows, but generally the eye-lashes seem to provide a fairly reliable index of the mature head-hair colour at all ages.

The brown hair-colour gradings in Fig. 1 are all based on the colour of the eye-lashes in both parents and children, the grade numbers being inserted *within* the squares and circles. As far as these observations go, they seem to confirm the Davenports' generalisation that no children are darker than the darker parent. The slight exceptions are seen in family 41, where a single child apparently oversteps the higher parental grade by 1 point, and in family 29 one child is apparently 2 grades darker than the darker parent. It will be noted that

it was in this family that an elder brother was similarly exceptional in eye-colour.

Red Pigment.

In Man red hair exists in many continuous shades from a light yellow-red to a dark chocolate-red. The Davenports provisionally suggest that the red or reddish-yellow pigment may exist in different dilutions and intensities, and also apparently, with or without the sepia brown pigment. This may possibly be so, but so far as my observations go a more simple scheme seems to explain the facts equally well. All the various shades of red hair known to me in humans, can, I think, be accounted for on the basis of the somatic association of a uniform red or orange pigment with each of the grades of brown pigment noted above. Thus if N1-N9 represent the various grades of the brown hair from cream-coloured to " black " and R a uniform red or orange pigment, then :—

N1+R=Silvery Cream	with	Red	producing	*Pale red*
N2+R=Pale Yellow	,,	,,	,,	*Light red*
N3+R=Yellow	,,	,,	,,	*Fiery red*
N4+R=Yellow-brown	,,	,,	,,	*Sandy red*
N5+R=Medium brown	,,	,,	,,	*Auburn red*
N6+R=Deep brown	,,	,,	,,	*Chestnut red*
N7+R=Dark brown	,,	,,	,,	*Chocolate red*
N8+R=Black-brown	,,	,,	,,	*Black-brown* (Red masked)
N9+R=" Black "	,,	,,	,,	" *Black* " (Red masked)

If the above interpretation of the facts is correct there is apparently no need to presume that the red pigment is found alone in the complete absence of the brown pigment. Indeed I imagine that such a presumption would be not only exceedingly difficult to establish by observation, but would also involve the more frequent occurrence of albinos in red-haired families than actually observed. Nor does it seem necessary to presume that the red pigment itself exists in various intensities and dilutions when its associations with the various grades of brown pigment appear to provide all the sorts of red observed.

With regard to the genetics of red hair in Man, in 1908 the

writer (15) published a brief account of his investigations in the Burbage families and at that time pointed out that Red hair seemed to behave as a Mendelian recessive to Brown which appeared to be dominant. These conclusions were based on the following observations :—

First, when both parents had red hair, all the children were red.

Second, when both parents had brown hair, *either* all the children were brown, *or* most of them were brown and a few were red.

Third, when one parent was brown and the other red, *either* all the children were brown, or about one half were brown and one half were red.

Since 1908 further investigations have been made which not only confirm and extend the previous observations but demonstrate clearly that in all the families where red-haired children appear, the brown-haired parents are without exception descended from families containing red-haired children. While, on the other hand, in those families in which red-haired children do not appear at all, the brown-haired parents are in many cases descended from families which have not thrown reds. All these observations seem to point to the recessive nature of red hair and the dominance of brown.

The adoption of the " presence and absence " method in genetics has, however, led us to regard such a character as red hair as hypostatic (rather than recessive) to brown hair, which is epistatic (rather than dominant). The Davenports' demonstration of the fact that the red pigment in human hair is a lipochrome distinct in its nature from the brown pigment, which is a melanin, goes far to confirm this idea. It would appear, therefore, that we must now regard the red pigment as due to the presence of a distinct unit-factor dominant to its absence.

On this view, presence of the factor for red should give visible red hair (except where it is masked by dark melanin as shown above), while absence of the factor for red should give hair with no traces of red. If (R) represents presence of red and (r) its absence, then all individuals should be gametically (RR), (Rr), or (rr). Red-haired individuals should be either (RR) or

(Rr), while brown-haired individuals should be all (rr), except as aforesaid in those cases where the grades of brown are so dark (8, 9 and 10) as to mask the red which may be present though invisible.

In order, if possible, to avoid the masking complication it seems necessary to consider those brown-haired individuals where there is presumably no masking of the red pigment, namely, in the lighter grades of brown 1-6. These low grade browns should be gametically (rr), and, therefore, cannot be expected to give red-haired children when mated together. Similarly these low grade browns (rr) when mated with reds (RR) or (Rr) may be expected to give *either* all reds (RR) × (rr) = (Rr), *or* one-half reds and one-half browns (Rr) × (rr) = 1 (Rr) + 1 (rr). While two red-haired parents (RR) or (Rr) should give *either* all red-haired children (RR) × (RR) = (RR), (RR) × (Rr) = 1 (RR) + 1 (Rr), *or* about 3 reds to 1 brown (Rr) × (Rr) = 1 (RR) + 2 (Rr) + 1 (rr).

In no case, however, do these expected results accord with the observed facts, for:—

First, the low grade browns *do*, in many cases, give reds when mated together.

Second, the low grade browns mated with reds in no case give all reds, so far as observed.

Third, two red-haired parents in no case give children with brown hair, so far as known.

The question arises, therefore, what is the explanation of the whole matter? So far as one can see, the case seems to admit of only one explanation, which though simple in itself, may present certain difficulties to the orthodox Mendelian. The suggested explanation is, that in order to have visible red in the hair two doses of the factor (R) are necessary (RR), and that in the presence of one dose (Rr) the red colour is either not developed at all, or only developed so slightly as to be masked by the melanin, and therefore invisible.

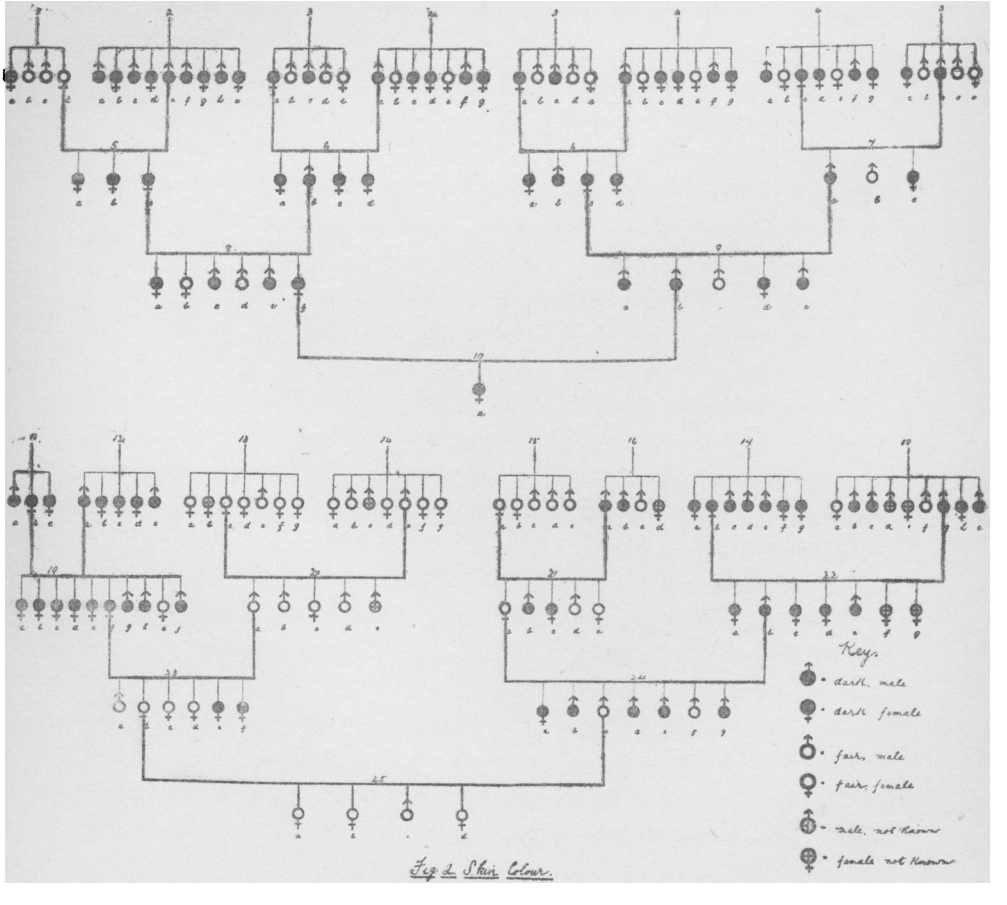
On this scheme two brown-haired parents (rr) would give *all* brown-haired children (rr). A brown (Rr) mated with a brown (rr) would give all browns (Rr) + (rr). Two brown (Rr) would give about one quarter reds 1 (RR) and three-fourths brown

2 (Rr) + 1 (rr), giving the novel and heterodox Mendelian ratio of 1 *Dominant to* 3 *Recessive.*

Similarly brown (rr) mated with red (RR) would give *all* brown (Rr). The brown (Rr) mated with the red (RR) would give about equal numbers of red (RR) and brown (Rr). While two red (RR) parents would give, of course, all red (RR) children.

On this scheme all the expected results seem to be in accordance with the observed facts. This suggested solution of the puzzling problem of the inheritance of red hair introduces a novel Mendelian ratio, which, if confirmed and extended to other characters in plants and animals, would be of considerable importance, inasmuch as it might go far to explain several

FIG. II.



well-known cases of apparent reversal of dominance in plants and animals which have so far remained inexplicable.

At the same time this suggested solution is advanced with considerable reluctance, because the writer feels that it would have been more acceptable, had it been first found in some cultivated plant or domesticated animal, where the matter could have been quickly and easily put to the test by conclusive experiments. The only excuse for putting it forward in the case of a human character is that no other explanation seems to be available.

Skin-Colour in "White" Races.

Davenport & Davenport (6) have recently published an important paper on the "Heredity of Skin Pigmentation in Man," in which the Skin-colours of typical Caucasians are divided into three categories, "Brunet," "Intermediate" and "Blond."

Professor H. E. Jordan, of the University of Virginia (17), in his microscopical studies on the melanin content of human skins, has since demonstrated clearly that in the "Brunet" the melanic pigment granules are more numerous than in the "Blond" skin.

The Davenports have collected numerous data from various sources, with the result that they find that their principle of the "Non-transgressibility of the Upper Limit" seems to apply to these skin-colours much in the same way as in hair and eye-colours. That is to say the higher and darker grade "Brunet" is dominant (epistatic) to the lower and lighter grades "Intermediate" and "Blond," while "Intermediate" skin-colour is dominant (epistatic) to "Blond," which is recessive (hypostatic) to both.

Consequently the children of "Brunet," "Intermediate" and "Blond" parents are in no case darker than the darker parent.

In order to test this generalisation in my material I have attempted to divide the skin-colours in the Burbage families into the three categories, "Brunet," "Intermediate" and "Blond." So far this attempt has not proved at all satisfactory, as there

seem to be various grades both of darkness and fairness in different families. A further attempt to divide skin-colours into ten grades as in the hair and eye colours has not been at all successful owing to the elusive nature of the different shades. At the same time it is evident that in many families there is a definite segregation of dark and fair skins, and in this respect the Davenports' suggestion that the higher and darker grade is dominant to the lower and lighter grade is certainly confirmed so far as my observations go.

The above pedigrees (fig. 2) will serve to illustrate the dominance of dark to fair skins, their segregation in the same family, and the apparent purity of the extracted fair individuals.

It should, however, be carefully noted that while the dark individuals in each family may be sensibly uniform in tint, yet in the different families there are different grades of darkness. A similar state of things appears also to exist amongst the fair individuals. It is quite possible, therefore, that a certain amount of overlapping might occur with these two categories "Dark" and "Fair" in certain pedigrees, though in the above pedigrees the two categories are quite distinct.

For instance, the dark members of families 19 and 22 are decidedly darker than the dark members of families 3 and 4, while the fair members of families 13, 14 and 20 are certainly fairer than the fair members of families 3, 4 and 8, yet the segregation of the dark and fair in families 3, 4 and 8 is quite palpable and clear cut.

Complexion Colour.

While investigating the question of skin-colour in the Burbage families, the writer has found his observations somewhat complicated by the different colourings of the complexion. Thus both dark and fair skins may be either pale or coloured. These differences in complexion colour appear to depend on the thickness of the skin, pale skins being thick and coloured skins thin. Generally speaking, a dark, pale skin makes a sallow or muddy complexion: a fair, pale skin a clear complexion: a dark, coloured skin a ruddy complexion: and a fair, coloured skin a florid complexion.

So far as my observations go, the pale thick skin seems to behave as a Mendelian dominant to the coloured thin skin which is recessive. At the same time, owing to the scarcity of coloured by coloured matings the evidence is not yet sufficient to establish the statement fully. The few families with two coloured parents have so far given all the children with coloured complexions. Cases of two pale parents giving either all pale, or a few coloured, are quite numerous, as are the cases of pale by coloured giving either all pale or about one-half with coloured complexions.

It is possible, moreover, that coloured complexions in adults really consist of two distinct classes, *viz.*:—"red," where the colouring extends over the whole of the face and neck, and "fresh" where the colouring is confined to a definite area in the cheeks. The precise relationship between these two classes is not yet known.

The above notes illustrate once more that the apparently simple question of the dark and fair colouring in "white" races is really a most intricate and complicated problem, which cannot be satisfactorily dealt with by the easy methods of the anthropologist. Sufficient evidence, however, has been obtained to show that, notwithstanding the apparently continuous nature of the pigmentation of the eyes, hair and skin of "white" races, the discrete Mendelian factors are at work in Man as well as in domesticated animals and cultivated plants.

Further investigation will no doubt determine many other Mendelian factors which are concerned in the heredity of colouring in Man, and also the interesting question as to how far these different factors behave as independent units, and what amount of association exists between them in the production of the visible soma of the two sexes.

With regard to the possibility of sex limitation or disturbance, it may be interesting to note that in the pigmentation characters so far observed only two families (quite unrelated) have shown any signs of such a phenomenon. Curiously enough in both families the dark hair and skin of the father were apparently transmitted to the daughters only, the sons (with a single exception in 1 family) having fair hair and skin similar to

those of the mother. The numbers (9 males and 10 females), however, are too small to attach much importance to the observation, and both may be merely curious coincidences.

Left-handedness.

The occasional appearance of left-handed individuals among normal right-handed brethren is a familiar fact, and there is a widespread popular belief that the peculiarity is inherited.

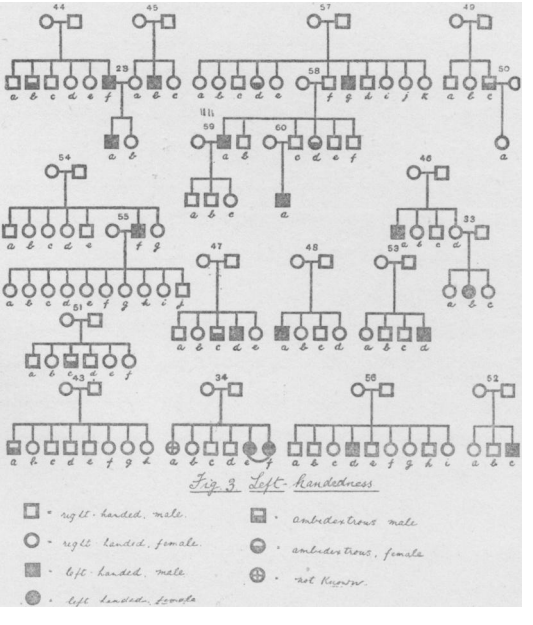
An interesting paper by Jordan (16) gives a concise history of the probable causes of left-handedness, together with a number of pedigrees which certainly support Jordan's conclusion that left-handedness is hereditary.

Jordan very cautiously suggests as a guiding hypothesis, that left-handedness may be a Mendelian character recessive to right-handedness which is dominant, and further, that ambi-dexterity may possibly represent a condition of imperfect dominance of the right-handed over the left-handed character.

In view of Jordan's paper, the writer has made some investigations with regard to the appearance of left-handedness in the Burbage families.

The following diagram (fig. 3) illustrates the results so far obtained.

FIG. III.



On Jordan's hypothesis that right-handedness is dominant and left-handedness recessive, most of the matings illustrated in fig. 3 would be of the nature of heterozygous right-handed individuals, which should give on the average one-fourth of the children left-handed. Counting the ambidexterous among the right-handed as Jordan suggests (imperfect dominants), and omitting the family with only one child, we get 74 right-handed to 14 left-handed children, a ratio nearer 5 : 1 than the expected 3 : 1. If, however, on the other hand, we regard the ambidexterous as left-handed, we get 67 right-handed to 21 left-handed children, a ratio very near to the expected 3 : 1. Further inquiry into the ambidexterous cases shows that, with the exception of one or two doubtful cases, the congenital bias was undoubtedly to left-handedness, the ambidexterity being apparently acquired as an adaptation to circumstances. In view of this it seems more reasonable to classify these ambidexterous cases as left-handed rather than right-handed.

Jordan's cases of similar parentage, omitting families with only one child, apparently give 21 right-handed to 12 left-handed children, a ratio nearer 2 : 1 than the expected 3 : 1, this, however, may be due to the fact that some of his families were admittedly incomplete, and consequently somewhat smaller than the Burbage families, which are fairly complete. Two left-handed parents have not yet been found in the Burbage families, but Jordan gives two cases in which the two offspring were left-handed in accordance with expectation. Jordan also gives 11 families of left-handed mated with heterozygous right-handed parents giving 24 right-handed and 22 left-handed children, which is in accordance with the expectation of equality. The Burbage families only supply one case of this mating giving one of each kind (family 28).

On the whole the evidence, so far as it goes, seems to favour Jordan's hypothesis that left-handedness in Man is a Mendelian recessive character, but his idea that ambidexterity is the condition of imperfect dominance of the right-handed over left-handed is not so far confirmed.

Hand-Clasp.

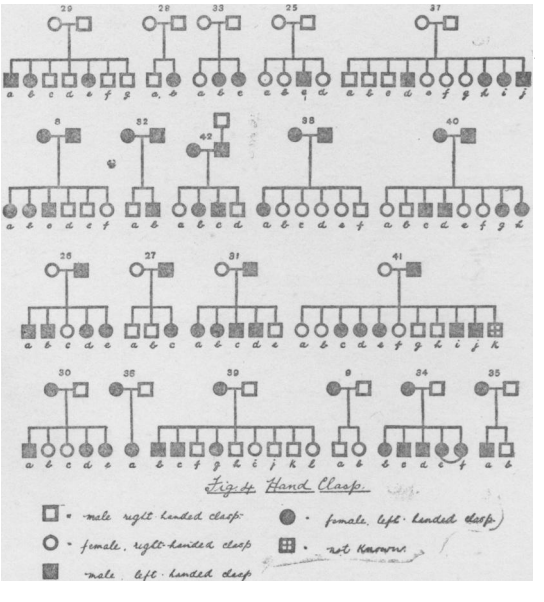
All persons naturally clasp their hands in one of two ways,

either, with the right thumb over the left thumb, in which case it is called a right-handed clasp, *or*, with the left thumb over the right thumb, in which case it is called a left-handed clasp. In practice one finds that certain nervous or self-conscious people when asked to clasp their hands are apt to wander with their thumbs, in such cases the position of the fingers provides an equally accurate index to their hand-clasp, if the fingers of each hand are alternated as they should be when the hand is properly clasped.

The manner of the clasping of the hands—right or left—seems to be congenital, being quite constant in very young children, and one naturally expects to find such a character inherited. The first to draw attention to this matter was apparently Dr. Frank E. Lutz, of U.S.A. (18), who, with the assistance of Prof. J. Arthur Thomson, of Aberdeen University, collected data for about 600 individuals. The result was certainly unexpected, inasmuch as neither position bred true, and did not seem to follow the Mendelian or any other system. Thus,

Two right-clasped parents gave 72.5 per cent. right-clasped children.

FIG. IV.



Two left-clasped parents gave 42.2 per cent. right-clasped children.

While right-clasped mated with left-clasped parents gave about 56 per cent. right-clasped children.

In view of these curious results steps have been taken to investigate the matter in some of the Burbage families. It was thought that a separate study of individual families might throw some light on the question. The following pedigrees (fig. 4) will suffice to illustrate the results obtained.

It will be seen that the observations made in the Burbage families give similar results to those collected by Thomson and Lutz. Neither right nor left position breeds true. Right by Right give 15 rights and 11 lefts, no family giving all rights. Left by Left give, curiously enough, the same result—15 rights and 11 lefts, no family giving all lefts. Right by Left and Left by Right give 20 rights and 27 lefts. All the families taken together with all kinds of matings give 50 rights and 49 lefts. In fact, there seems to be an equality of rights and lefts all round, no matter what the parents are. Neither does there seem to be any question of sex limitation or disturbance, for out of the 67 males and 73 females concerned there are 37 right males, 34 right females, 30 left males, and 39 left females. Naturally the question arises whether in a case of this kind we are really dealing with an hereditary character at all, and yet it is difficult to imagine that a perfectly discontinuous, congenital, and apparently instinctive character like hand-clasp is not inherited.

One thing, however, seems clear, and that is, that the inheritance, if any, is not Mendelian, at any rate so far as one can analyse it from the data. Somatic segregation is evident, but there is no dominance, and above all, no gametic purity, so far as one can see. It is often pointed out, with truth, that dominance is not an essential part of Mendelism, only segregation matters. The case of hand-clasp, however, suggests that even segregation (somatic) is not always evidence of Mendelian heredity, but that pure breeding alone is the true test. The case of hand-clasp is particularly interesting inasmuch as it is, so far as the writer knows, the only human character investigated that defies Mendelian analysis, and as such it

appears to constitute a single real exception to the general rule.

A comparison of figs. 3 and 4 shows at a glance that in dealing with the inheritance of right and left-handedness (fig. 3), and right and left hand-clasp (fig. 4), we are up against two totally different characters, and that, however much they may appear to resemble one another superficially, their fundamental natures must be wide asunder.

Tuberculosis.

In venturing to touch upon such an intricate and complicated question as tuberculosis, the writer is well aware of the many difficulties involved, but the question is of such overwhelming importance that a few observations noted while conducting other researches in the same families may possibly be of some interest to those engaged in a study of the question from the point of view of Eugenics.

The following pedigrees of the adult Burbage families that have suffered from the disease deal only with pulmonary tuberculosis and comprise three definite categories:—

First, those who have died from the disease.

Second, those who are seriously affected with it.

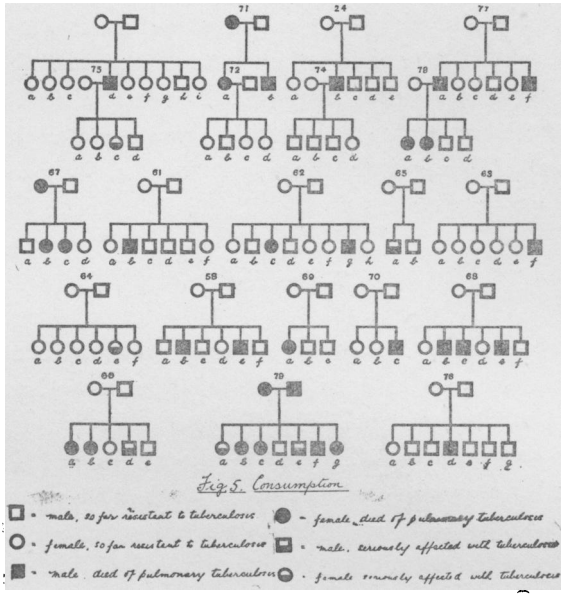
Third, those who have resisted it.

The first and second categories are alas self-evident. The third category consists of adult individuals who, so far, have proved themselves resistant to infection, in the sense that the disease, if present at all, has never seriously affected them, though it has proved fatal in their homes.

From the point of view of heredity, the significance, if any, of the above facts seems to lie in the following observations:—

First, when both parents are resistant to the disease (*i.e.*, have come under infection but have not been seriously affected by it) and yet have one or more children who have succumbed to its ravages, the death-rate is about one-fourth. Thus out of 78 adult children of such parents, 18 died of the disease, 3 have been seriously affected by it, and 57 have so far proved resistant.

FIG. V.



Second, the single case in which both parents died of the disease produced 7 children, of whom 4 have died of the disease, 2 have been seriously affected by it, and 1 has so far proved resistant.

Is it possible that the power of resistance to tuberculosis in certain individuals is due to the presence of a definite factor which is absent in those who succumb to the disease? Owing to the extraordinary difficulties which beset this question the above suggestion is only submitted with a note of interrogation, in the hope that some expert student of tuberculosis will apply it and test it in a more extended form, with due regard to the many environmental complications involved.

Musical Temperament.

That certain individuals have a natural disposition for music, while others have not, is evident to the most casual observer. That this natural disposition or temperament is innate and hereditary there can be little doubt. Musical associations

and careful training can, of course, do much in enriching the musical qualities in an individual of a musical disposition, but in the absence of the musical temperament these outer stimuli are practically powerless. My observations in the Burbage families go to show that individuals with a natural disposition for music almost always display it early in life, usually between the 2nd and 6th year. Musical children soon pick up airs and melodies after hearing them a few times and are found constantly humming them over to themselves, almost unconsciously. So far as my experience goes, non-musical children do not do this, when they are not silent they either drone monotonously or are merely noisy. Musical children as they grow up begin to harmonise naturally, putting in their own parts without any tuition. If their singing voice is poor they may take up the playing of some instrument, otherwise they are content with mere humming or whistling.

In musical children and adults all this is done naturally and spontaneously without conscious effort, and in many cases without knowing a note of music throughout their lives. Of course, in all musical individuals there are found varying degrees of ability in regard to powers of expression, musical memory, sense of time and rhythm and other musical *minutiæ*, all of which may be developed to a considerable extent by careful training. There appears also to be a distinct class of non-musical individuals who are practically tone-deaf, who for instance are unable to distinguish between the "National Anthem" and the "Old Hundredth," and to whom apparently there is little, if any, distinction between low and high notes, such cases, however, are rare, probably as rare as the talented musician among ordinary musical people. There seems also to be a striking difference between musical and non-musical persons in the nature of their ordinary speaking voice, the musical individual speaks naturally in melodious tones, the voice rising and falling with correct intervals, while the non-musical individual speaks naturally in monotones without a trace of melody. So far, only one case has been observed by the writer where a non-musical individual has a melodious speaking voice, and not a single case where a musical individual has a monotonous voice.

A study of the distribution of musical and non-musical

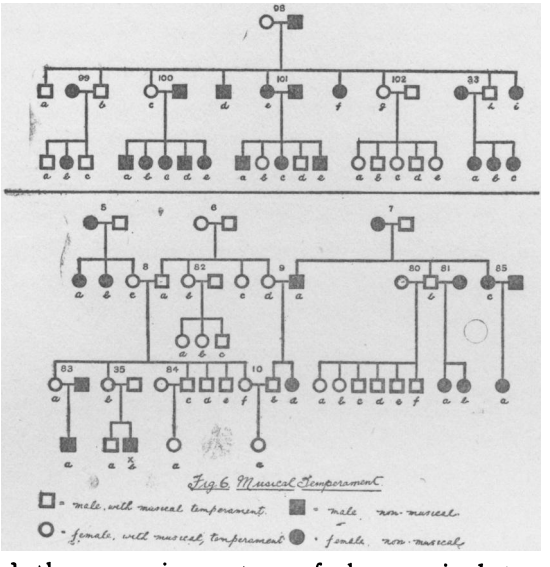
individuals in the Burbage families led the writer (15) to point out in 1908 that the musical temperament appeared to behave as a Mendelian recessive character, the ordinary non-musical temperament being dominant. For it was found that when both parents were musical all the children were musical. When neither parent was musical *either* none of the children was musical, *or* a few were musical and most of them were not. When one parent was musical and the other not, *either* none of the children was musical, *or* about one-half were musical and one-half not.

Professor F. O. Grover, of Oberlin College, U.S.A., has kindly informed me that his investigations in some American families confirm the above results. Further observations made here since 1908 generally confirm and extend the previous work. One interesting case, however, has recently turned up which seems to be an exception to the rule that when both parents are musical all the children are musical. This is the case of a boy in family 35 (*b*) (fig. 6), 7 years old, who though fond of singing, cannot at present sing an air at all correctly, it is not so much that he sings out of tune, but he sings a kind of monotonous vamp that is not altogether in harmony with the air. Whether this is due to some defect of control of the vocal chords, or whether it is due to a non-musical temperament is a question that may be decided at a later stage. This boy's elder brother is a sweet and correct singer with an undoubted musical temperament, as are both his parents.

The following pedigrees will serve to illustrate the genetics of the musical and non-musical temperaments.

All the individuals classed as "musical" in the following pedigrees have given some definite expression of their musical temperament, in one way or another, either as singers, players, whistlers or hummers. On the other hand, the individuals classed as "non-musical" have not done so, that is, so far as my observation of them has gone. It is, of course, possible that a few of those classed as "non-musical" may be of the nature of mute musicians (especially those early affected with deafness), but in any case, if such do exist they must be rare. The pedigrees given serve to illustrate the dominance of the non-

FIG. VI.



musical and the recessive nature of the musical temperament, the segregation of these two characters in the same family and the apparent purity of the extracted recessives.

The above results raise two interesting points:—

First, the fact that the musical temperament is inherited on Mendelian lines is interesting because as a temperamental character it is probably of a different order from purely physical or structural characters like pigmentation and left-handedness and the question naturally arises if a psychical character like musical temperament follows simple Mendelian rules, may not other characters of a similar nature, but more important perhaps to the race from the Eugenic standpoint, do so also? This opens up possibilities of a wider field of research for the worker in human Genetics and Eugenics.

Second, the fact that the musical temperament behaves as a recessive character and not a dominant, would seem to imply, according to the "presence and absence" method, that an individual is non-musical owing to the presence of an inhibitory factor preventing the expression of the musical temperament which is hypostatically present in everyone.

In other words, it would appear that while probably everyone possesses the fundamental musical temperament, yet owing

to the presence of an inhibitory factor non-musical people are unable to give expression to it, whereas, on the other hand, in the absence of such an inhibitor the musical temperament is expressed and the individual is musical.

The interesting question as to whether an individual with a double dose of the inhibitory factor differs in any way from an individual with a single dose, cannot be answered on the present evidence. It is tempting, however, to suppose that a tone-deaf person differs in gametic constitution from an ordinary non-musical individual.

Genetics and Eugenics.

In the above paper on Mendelian heredity in Man, an attempt has been made to show how the new principles of Genetics can be applied to Man with some degree of success. In studying the inheritance of the more simple physical characters in Man, it is evident that we are as yet only feeling our way towards the solution of certain larger and more complicated problems which are of vital importance to the human race. The future of Eugenics depends very largely on the solution of these problems. I do not wish for one moment to suggest that the art of Eugenics has been born before its time, but I do feel that before we can venture to apply the scientific principles of Genetics to human life we must first make our foundations sure. For this reason, I am convinced that a good deal of spade work in human Genetics will have to be done before any considerable amount of practical good can be accomplished in Eugenics. Eugenics is simply applied Genetics, and *sound Eugenics can only be founded on sound Genetics.*

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